A Web Environment for Geometry

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Abstract. The Web Geometry Laboratory, *WGL*, is a blended-learning, collaborative and adaptive, Web environment for geometry. It integrates a well known dynamic geometry system.
In a collaborative session, exchange of geometrical and textual information between the user engaged in the session is possible.
In a normal work session (stand-alone mode), all the geometric steps done by the students are recorded, alongside the navigation information, allowing, in a latter stage, their teachers to "play back" the students sessions, using that info to assert the students level and adjust the teaching strategies to each individual student.
Teachers can register and begin using one of the public servers, defining students, preparing materials to be released to the students, open collaborative sessions, etc.
Using an action research methodology the *WGL* system is being developed, validated through case-studies, and further improved, in a cycle where the implementation steps are intertwined with case studies.

Keywords: adaptive learning, collaborative learning, blended-learning, dynamic geometry

1 The Web Geometry System

The *Web Geometry Laboratory* (v1.4) is a Web client/server application; the server must be hosted by a Web-server (e.g. Apache server) the clients may use any Web-browser available. The database (to keep: constructions; users information, constructions permissions, etc.); the dynamic geometry system (DGS), JavaScript applet; the synchronous and asynchronous interaction, are all implemented using free cross-platform software, namely GeoGebra, PHP, JavaScript, AJAX, JSON, JQuery and MySQL. Also Web-standards like HTML5, CSS stylesheets and XML. The *WGL* is an internationalised system with the English language as the default language and already localised to the Portuguese and Serbian languages. It is an open-source system[5], versions of the server are available to be installed on Linux systems (or other systems through virtual machines).

[5] http://webgeometrylab.sourceforge.net/

The last version of WGL (1.4) introduces a total separation between development branches: stable; testing; unstable (development), given a added stability to the public (stable) server and allowing a public availability of the code. Apart many small improvements the major new features are: the text chat; the exchange of geometric information between the group and individual windows and the saving of the students work to their own scrapbook, when in a collaborative sessions; the "record & play" of student's sessions, i.e. the adaptive module (at a prototype stage in [8]); the JavaScript/HTML5 DGS applet (instead of the Java applet).

Two instances of the *WGL* server are available, one in Portugal,[6] another in Serbia.[7] Users can log on to the system using the anonymous student-level user, but without access to collaborative sessions. For more advanced use, a user must register and then be confirmed by the administrator. During the last three years these systems have been intensively used, e.g., for testing collaborative learning in teaching geometryr [2,7,8,10]. Please feel free to contact the authors if you want to use the *WGL* platform, accessing the platform as a teacher.

In any *WGL* server there are four distinct types of users: administrators, teachers, students and anonymous visitors. The administrator(s) main role is the administration of teachers. They have also access to the log-in information off all users, information that can be used to streamline the server.

The teachers are privileged users in the sense that they will be capable of defining other users; their students. In the beginning of each school year the teachers should define all their classes, the students in each class and, if needed, the aggregation of the students into groups

The students, each linked to a given teacher, are able to work in the platform, performing tasks created by their teachers and/or pursuing their own work. The students are unable to create other users.

Finally, the anonymous visitor is a student-type user, not linked to any teacher and because of that, unable to participate in collaborative sessions. The purpose of this type of user is solely to allow unregistered users to test the *WGL* platform.

There are two distinct modes for the students to interact with the *WGL* system. The collaborative sessions and the regular (stand-alone) sessions. These two distinct modes are controlled by the teachers. In a collaborative session the students, working in groups, have some specific assignment to fulfil and they will do it in a collaborative way, exchanging geometric and textual information to reach the common goal. In a regular session the students will be working alone, they can share constructions with the other users of the platform but all this exchange of information will be asynchronous.

[6] `http://hilbert.mat.uc.pt/WebGeometryLab/`
[7] `http://jason.matf.bg.ac.rs/wgl/`

2 The Collaborative Module

Planning a collaborative working session the teacher has to decide how to group the students and the design of the tasks to be solved collaboratively, i.e., prepare a set of geometric constructions, starting points for tasks to be completed during the class; illustrative cases; etc.

In a *WGL* collaborative session the students will solve the tasks proposed by their teachers, being able to exchange geometric and textual information, producing the geometric constructions in a collaborative fashion.

The students engaged in a collaborative session will always be in working groups, with access to the material prepared by the teacher and with access to two DGS applets. One of those DGS applets is for their own work, the other is where the group construction is being done. The *group-construction* is shared by all the members of a given group, one of the students will have the lock over the construction, all the other group members will see the work being done (synchronised every 20s). At any given moment the student can release the lock, which can be claimed by any student in the group.

At the same time, the students has their own work-space, this can be used to: follow the work that is being done by the group representative; develop their own constructions; to anticipate the group construction; to develop auxiliary constructions. In this work-space the saving of the work being done is the responsibility of the student.

The students have the possibility of exchange constructions between DGS workspace windows. The students without the lock should be able to "import" the group construction to his/her own work-space. The student with the lock adds to that, the possibility of exporting the construction to the group work-space. A chat is provided to allow the exchange of short messages between all the members of the group, including the teacher.

Apart from being responsible for setting the collaborative session and being able to assess its results at the end, the teacher has also access to a DGS work-space window where he/she can follow the work of all the groups and all the individual students in each group.

3 The Adaptive Module

To be able to build individual student's profiles and/or individual learning paths, the system collects information about the student's interactions when in the stand-alone mode, i.e., in a regular work session.

The system records navigation and also geometric information for each student. The navigation information is a plain list of all the pages visited with enter and exit time-stamps. The geometric information is recorded when the student is using the DGS applet, using JavaScript listeners of the DGS application programming interface. We record every step done by the students.

At a later stage the student's teacher is able to see the work done by the student, play step by step, play in a regular speed, play in a fast forward fashion.

In this way the teacher can analyse the path used by the students to solve a given task, getting information that can be used to assert the student's van Hiele level [1].

4 Access to the System

The *WGL* public servers can be used by any interested teacher. The International/Portuguese server is `http://hilbert.mat.uc.pt/WebGeometryLab`, the Serbian server is `http://jason.matf.bg.ac.rs/wgl`. After registration (subject to validation) a teacher can create classes and use the system as a geometry laboratory or as platform for homework tasks. In a stand-alone fashion or in collaborative sessions.

We performed two different set of studies, one in Portugal, in classroom mode, and another in Serbia, in remote access mode[8]. The first set of studies was done using *WGL* version 1.2, still without the group-wise communication channel (chat). The second set of studies were done using *WGL* version 1.3, already with the chat communication channel, among other developments done in the platform. The platform was positively received by teachers and students, improving their learning experience [10]. The case-studies were/are used to improve the system but also to publicise the system, training teachers in its use.

A forum (phpBB forum) is provided to allow the exchange of information between users.

5 Conclusions and Future Work

Related Systems There are several DGS available (see [11] for a comprehensive list) but none of them defines an environment where the DGS is integrated into a learning platform with collaborative and adaptive features. In [5,6,9] we can find accounts of DGSs and geometric automated theorem provers (GATPs) integration and the integration of those tools in learning environments but always partial integrations not building any kind of collaborative, adaptive blended-learning platform. Some learning environments in the area of geometry have been developed, e.g. Tabulae [3] and GeoThink [4]. The *WGL* distinguishes itself relying on an external DGS, allowing in this way to possess a full fledged DGS, well known by its users and supported by its developers. The well grounded permissions system and the capability that this opens for a personalised contact with the platform, is also something in favour of *WGL*. The many case-studies already conducted, validating the *WGL* goals, and the internationalisation, i.e. the ability to receive translations into different languages (Tabulæ lacks this feature), are also positive points for *WGL*.

[8] *Web Geometry Laboratory: Case Studies in Portugal and Serbia*, submitted to *Educational Technology Research and Development*, May 2015

Conclusions and Future Work At the moment the adaptive module only collects the student's information and allow the teachers to "play" that information. A first step ahead, already planned, will give the teachers the possibility of building students profiles or individualised learning paths. A second, more ambitious, step would give the system some capabilities of automatic construction of those profiles and/or learning paths.

A second development planned is the integration of a GATP. To be able to provide a formal validation of geometric properties, e.g. "*two lines are perpendicular, because ...*" and also to support the automatic or semi-automatic adaptive features, e.g. one-step guidance, formal reasoning and visual proofs.

The Web Geometry Laboratory is a blended-learning, collaborative, adaptive, Web environment for geometry already being used by teachers in Portugal and Serbia and we expect that its user base can grown not only in those countries but also in other countries.

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